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Acknowledgements

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Abstract

The objectives of this project are to continue the enhancements to the combined Broadband Electromagnetic and Full Encirclement Unit (BEM-FEU) technologies and to evaluate the system's capability in the laboratory and the field. The BEM instrument can, with proper calibration, estimate the condition of metal pipe walls without the need to remove coatings. The FEU automates the movement of the BEM sensor about the exterior of the pipe and is suitable for use in a keyhole excavation. This work was collaborative between the Gas Technology Institute (GTI) and the Rock Solid Group Pty Ltd (RSG).

Executive Summary

The primary goal of this work was to provide a field demonstration of the Broadband Electromagnetic (BEM) sensing technology with the Full Encirclement Unit (FEU) to rapidly gather data about pipe wall conditions. The BEM sensing technology provides information on the wall thickness of metallic pipes; it does not require that the coating be removed. Prior to this work, the Hand Scanning Kit (HSK) was the standard means of applying BEM to this type of inspection. An automated method of moving the HSK over the area being inspected would speed operations and reduce errors.

Significant improvements were made to the HSK and its supporting software over the course of the project. A number of new sensor antennae that had been under development were fabricated and tested. Arrays of up to 6 antennae have been tested; arrays can significantly reduce the time an inspection requires. Both 1 inch and 2 inch antennae are available in these arrays, allowing the user a choice of scan resolutions.

One of the precursors to the demonstration was the development of a field ready version of the FEU. The FEU is an automated platform that can be applied to a pipe in a small excavation to automatically scan the entire circumference. A prototype version of the FEU had been constructed prior to this project work. Multiple improvements were required to the FEU to improve both its robustness and its ease of use. The BEM antenna and cabling also needed to be integrated with the FEU.

Another precursor was the laboratory verification of the BEM-FEU system. Samples of used, metallic gas pipes were obtained from participating utilities. These pipe samples were exhaustively characterized using the system and verified with secondary techniques. This process was iterative with improvements to the BEM and the FEU. In addition to the FEU improvements, new antennae for the BEM increased its resolution.

The first field demonstrations were carried out at a utility near to GTI. These were on abandoned cast iron mains and led to further improvements both in the equipment and the procedures. This experience was valuable preparation for more extensive field trials at remote sites. Field demonstrations were carried out at an additional four sites. The detailed site reports are included in this report.

In additional to technical reporting, a field operator's manual for the system was prepared. The manual reflects the lessons learned from field demonstrations. A presentation on the project and the BEM system was presented to the American Gas Association (AGA) Corrosion Committee in October of 2010.

The outcome of this development has resulted in the creation a fully automated scanning system by combining these technologies. The new development is now able to make use of a dedicated software system known MetCon as well as smaller BEM sensors enabling more detailed inspection information about ferrous gas lines.

Task Work as Proposed

The objectives of this project were to continue the enhancements to the BEM-FEU system and to evaluate the systems capability in the laboratory and in the field. A number of practical issues had been identified in earlier phases of the project that needed to be addressed within this project, including:

1. Demonstrating the application of the Excavation Inspection System (EIS – a precursor to the Keyhole Inspection System) unit at the GTI laboratories in Chicago and determining readiness to undertake field demonstrations.

2. Undertake field demonstrations for utility sponsors to show the field worthiness of the current EIS unit.

3. Ruggedizing and making field-worthy the FEU system for standard field applications.

4. Expanding the EIS device to allow for the use of the 4, 5, and 6 sensor HSK antennae. Currently the EIS is limited to the use of the 1, 2, and 3 sensor HSK antennae. This would greatly increase the speed of survey coverage therefore reducing the scanning time by up to 50%.

5. Upgrading the HSK operating and acquisition software to allow for a more "user friendly" parameter selection by the operator as well as customizing it for the USA industry – units, PipeType database, etc.

6. Development of a full set of 1-inch sensor HSK antennae suitable for incorporation into the EIS and future KIS devices.

7. Incorporating the 1-inch sensor HSK antennae into the acquisition software. The current software is suitable for 2-inch sensor HSK antennae only. Further expansion of the PipeType database (now known as the Database) to cater to the 1-inch sensor HSK antennae.

8. Develop a user manual for the EIS and KIS which consists of the FEU and HSK.

The following tasks were proposed in order to address the above objectives and issues.

Task 1 - Enhancement of the BEM System

The purpose of this task is to enhance the BEM system for use in field situations. The focus is to have the BEM fully integrated with the FEU for use in both traditional and keyhole excavations. The BEM can also be used to perform hand-scans in traditional excavations.

Task 2 - Laboratory Testing and Evaluation

The purpose of this task is to test and validate the BEM-FEU system. Laboratory and bench testing was carried out at the GTI facility and the data post-processed by RSG. This work is reported in detail.

Task 3 - Perform Field Evaluations

The purpose of this task is to perform field evaluations of the BEM and the FEU. Multiple field evaluations have been carried out at four participating utilities. Rock Solid has prepared detailed reports of these field trials; these are attached to this report.

Task 4 – Guidelines and Procedures

The purpose of this task is to transfer the knowledge gained during the execution of the project to the end users. An operator's manual, covering the set up and operation of the BEM-FEU system will be prepared by GTI and Rock Solid. Utility feedback from the field evaluations will be incorporated into the manual. A presentation on the project findings will be given at a public forum.

Technical Discussion and Accomplishments by Task

The following section describes the project activities and accomplishments by task.

Task 1 - Enhancement of the BEM System

The purpose of this task was to enhance the system for use in field situations. The goal was to have an enhanced HSK fully integrated with the FEU for use in both traditional and keyhole type excavations. The HSK can also be used to perform hand-scans in traditional excavations.

RSG performed several enhancements of the HSK and its software developed a prototype 1-inch antenna in Australia. In this phase of the development project the 1-inch sensor development was taken off the drawing board and taken through to a final product. The 1-inch sensor was designed and built into the full set of 1-way to 6-way antennae having similar characteristics to the initial 2-inch sensor antennae but having the sensitivity of up to four times that of the 2-inch sensor antennae. An example of an array of 1 inch antennae is shown in Figure 1.

The 1-inch antennae underwent a broad range of tests and trials in Australia to minimize the chance of complications when used alongside the FEU. Since the FEU was housed at the GTI facilities in Chicago testing of the 1-inch antennae with the FEU was carried out by GTI. The resulting antennae are now produced as waterproof units able to scan pipes even if submersed in water.

Towards the end of Phase 2 a clear need was identified to simplify the HSK and BEM data acquisition software. The original software developed in 2004 underwent numerous versions and was the software used extensively up to 2009. The HSK2004 software was developed in Australia and allowed for the metric market only. Extensive use in the USA recognized the need for a more flexible system capable of incorporating the imperial measuring system as well.

In addition the HSK2004 software was used almost exclusively by RSG personnel or personnel in continuous close communication with RSG. Although the software was relatively simple to operate it was evident that a more user friendly software was necessary. Basic concepts of the new software were in place in late 2008 and the instigation of the Phase 3 development project spurred these concepts towards realization.

Serious development of the new software known as MetCon was commenced in March 2009 and significant development continued through to September 2009 following which fine tuning and debugging has been taking place ever since. The MetCon software is now available as a commercial product replacing the HSK2004.

Amongst numerous enhancements the MetCon software can now be run in metric or imperial measuring units. It is also fully integrated to allow the user to select whether scanning measurements are undertaken using the 1-inch or 2-inch antennae. The PipeType capture and analysis parameters have been replaced with a Database entry selection which today has a broad range of nominal wall thickness and metal type parameters. Further enhancements exist allowing significantly more control over the display for the operator.

As mentioned above as part of the MetCon development the PipeType file was renamed the Database file and now contains not only the 2-inch sensor calibration files but also houses numerous 1-inch sensor files. The selection of the appropriate Database entry necessary for appropriate scanning and data capture is now also much more intuitive then in the HSK2004 version of the software. While the selection of the PipeType was based on having to know/understand a certain nomenclature the MetCon Database selection is based purely on information entered into the software by the operator based on site and existing pipe parameters. The selection of the appropriate Database is now fully automated based on the information supplied by the operator.

GTI has made several enhancements to the full encirclement unit (FEU). The FEU is now, reversible allowing the pipe to be scanned in both directions. This is critical in keyhole applications where the FEU may need to be rotated 180 degrees in place in order to scan a larger area of the pipe through the keyhole excavation. The scan reversal allows all of the pipe data to be acquired in the same direction regardless of the orientation of the FEU head. Several modifications were made to seal the mechanism against the intrusion of water and dust. The FEU now has an adjustable foot to accommodate pipes of different diameters. Previously, this had been accomplished by having a set of spacers specific to each pipe diameter, shown in Figure 2. The new system, shown in Figure 3, uses a sliding adjustment, eliminating spacer change out.

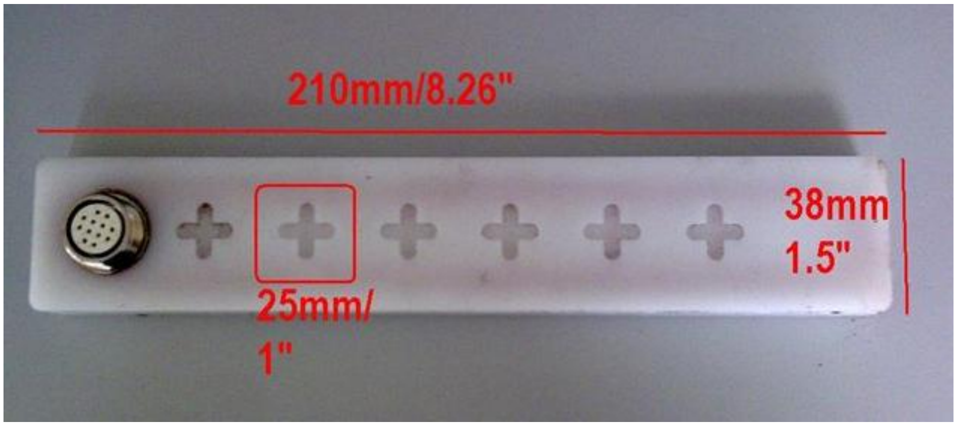

Figure 1 – A New 1" by six-element Antenna

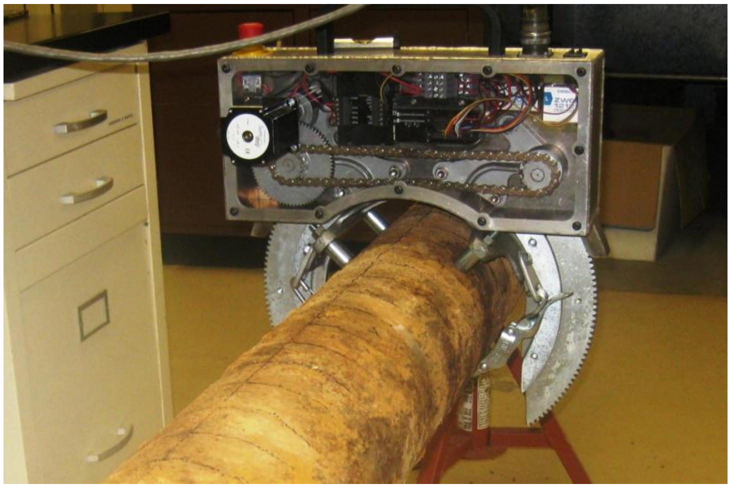

Figure 2 – Original FEU with Spacers

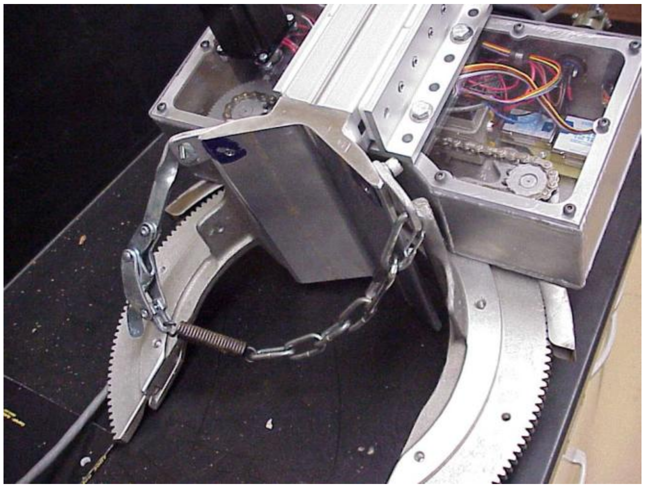

Figure 3 – Modified FEU with Adjustable Centering

Task 2 - Laboratory Testing and Evaluation

The purpose of this task was to test and validate the enhanced BEM-FEU system. Laboratory and bench testing was carried out at the GTI facility and the data post-processed by RSG.

Late in 2008 the HSK1000 and FEU prototype device was supplied to GTI from the RSG facilities in Melbourne, Australia. Managing director and owner of RSG, Mr. Martin Roubal visited the GTI offices in Chicago in late November, 2008 for a total of seven (7) days to aid in the training of GTI staff in the use of the HSK1000 and FEU devices. Numerous scans were undertaken at GTI's laboratories in combination with the project manager at that time, Ms Susan Borenstein and Mr. Joe McCarty. Part of the visit included the dismantling and setting up of the devices and capturing of BEM data by GTI staff to allow for autonomous scanning procedures by designated GTI personnel.

A set of standard target pipes was fabricated and used to verify the operation of the combined system. GTI began testing the BEM unit and found that new spacers for the FEU were needed. A minor software problem was found when using the BEM unit after sending data to Rock Solid, a calibration plate was obtained from Rock Solid, Rock Solid visited GTI and the problem was corrected. GTI proceeded to undertake numerous in-house scans as well as scans from a local gas utility; RSG processed and reported on the resulting captured data. Extensive trials and scans demonstrated the robustness of the device and the suitability of the HSK1000 and prototype FEU to be engaged in field trials and demonstrations as required by the project.

The ten pipes selected for inspection and validation of the BEM system were cut, metallurgically mounted, polished and etched to confirm the identity of the materials. The BEM tool is capable of scanning cast iron, ductile iron and carbon steel in a wide range of wall thicknesses. Different ferrous metals have different "signatures" that require different settings and calibrations of the HSK instrument. The BEM system is a comparative process and the instrument is calibrated for a range of pipe types and thicknesses. The differences in metallurgical structure of the cast iron, ductile iron and carbon steel are very important. If the basic pipe type information is not keyed into the tool correctly the real-time processing software will analyze the captured data against incorrect parameters resulting in the generation of incorrect field screen displays. This can always be corrected in post processing, if the material type is known after the fact. Table 1 is a list of the pipe materials chosen for examination with the BEM system.

Pipe 1 (Figure 4 and Figure 5) with machined defects was examined using the 1, 2 and 3 sensor scanners, with and without the FEU. The data files were submitted to Rock Solid for review and analysis.

Nodular iron, also referred to as ductile iron, is a gray cast iron type that has been treated with a nodularizing agent so that all or the major portion of its graphitic carbon has a nodular form as cast. Pipes A (Figure 6), C (Figure 10), G (Figure 18) and H (Figure 20) are nodular (ductile) iron. This microstructure is illustrated in Figure 7, Figure 11, Figure 19, and Figure 21 for the pipe samples.

Gray cast irons generally contain more than 2 percent silicon, and the carbon exists as flakes of graphite embedded in a combination of ferrite and pearlite. Pipes D (Figure 12), E (Figure 14) and J (Figure 24) are gray cast iron. This microstructure is illustrated in Figure 13, Figure 15, and Figure 25 for the pipe samples.

Plain-carbon steel is a metal alloy, a combination of two elements, iron and carbon, where other elements are present in quantities too small to affect the properties. Pipes B (Figure 8), and I (Figure 22) are carbon steel. This microstructure is illustrated in Figure 9 and Figure 23 for the pipe samples. High strength low alloy (HSLA) steel is a type of alloy steel that provides better mechanical properties or greater resistance to corrosion than carbon steel. Pipe F (Figure 16) is HSLA steel. This microstructure is illustrated in Figure 17 for the pipe sample. HSLA steels vary from other steels in that they aren't made to meet a specific chemical composition, but rather to specific mechanical properties.

Table 1. Pipe materials

PIPE	MATERIAL TYPE
A	nodular iron Type 1 size 6
B	steel ~1020 grade
C	nodular iron Type 1 size 6
D	gray iron Type VII A and B
E	gray iron Type VII B
F	~.08C high strength low alloy steel
G	nodular iron Type 1 size 5
H	nodular iron Type 1 size 6
I	steel ~1025 grade
J	gray iron Type VII A and B

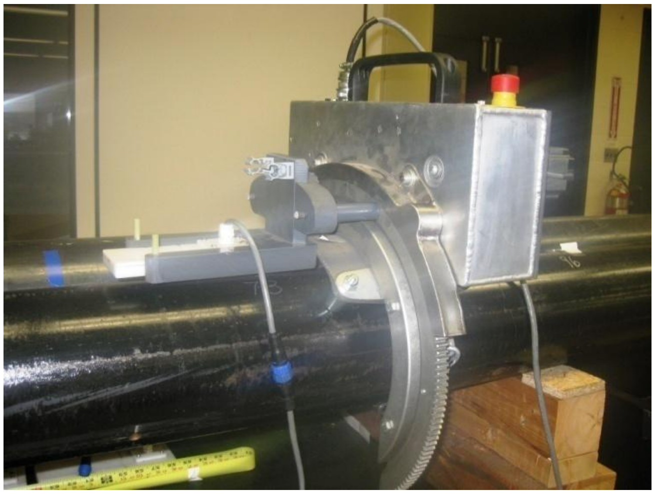

Figure 4. Pipe No. 1 with machined defects showing FEU and single scanning antenna

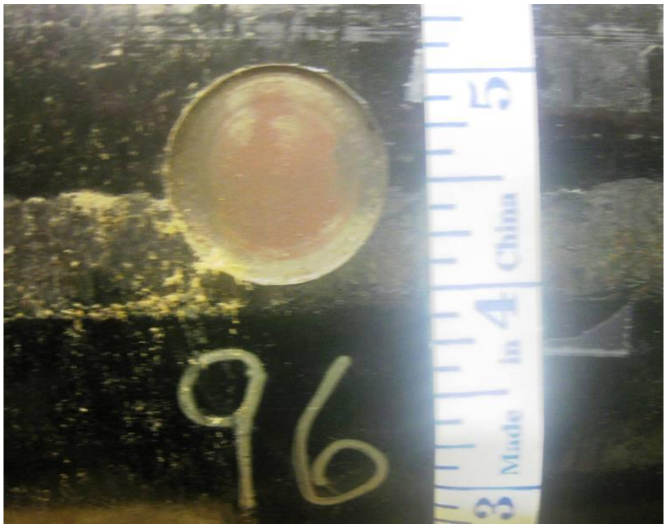

Figure 5. Machined defect on Pipe 1

Figure 6. Pipe A- Nodular (ductile) iron pipe with lining

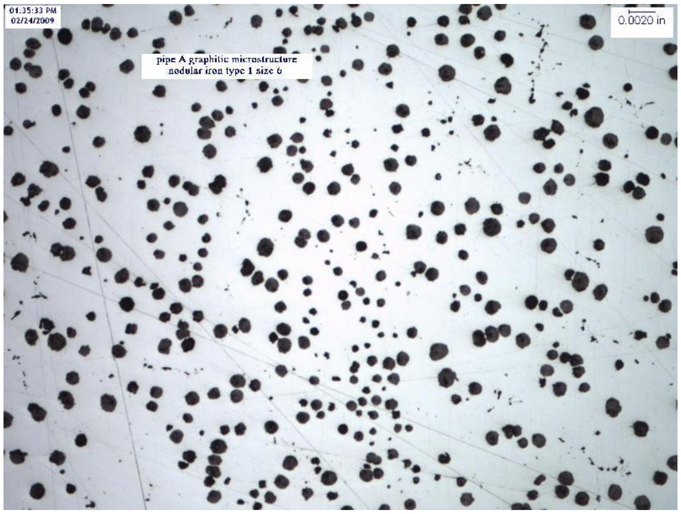

Figure 7. Pipe A nodular (ductile) iron Type 1 size 6

Figure 8. Pipe B- Carbon Steel pipe

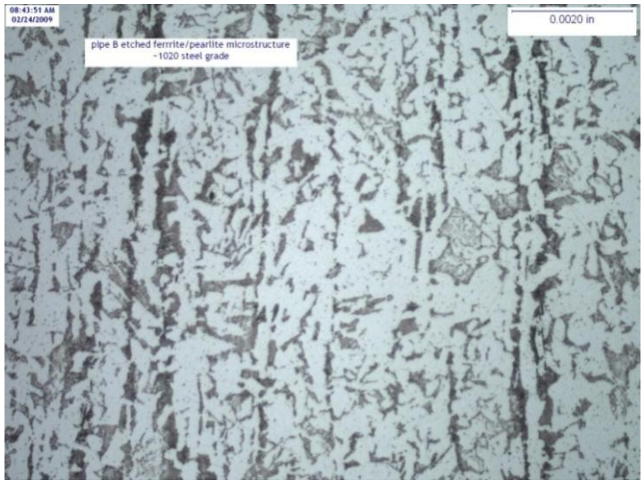

Figure 9. Pipe B Carbon steel, ~1020 grade

Figure 10. Pipe C Nodular (ductile) iron

Figure 11. Pipe C Nodular (ductile) iron Type 1 size 6

Figure 12. Pipe D Gray Cast Iron pipe.

Figure 13. Pipe D Gray (cast) iron Type VII A and B

Figure 14. Pipe E Gray cast iron with internal lining

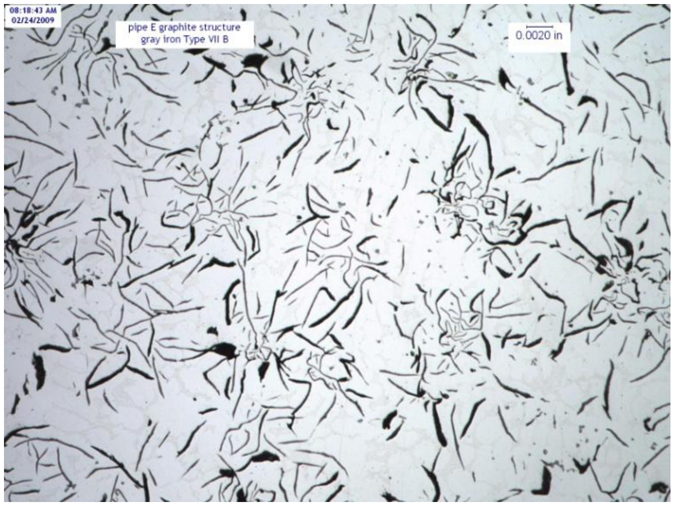

Figure 15. Pipe E Gray cast iron Type VII B

Figure 16. Pipe F Coated HSLA steel

Figure 17. Pipe F High strength low alloy steel (~0.08C)

Figure 18. Pipe G. Nodular (ductile) iron lined pipe

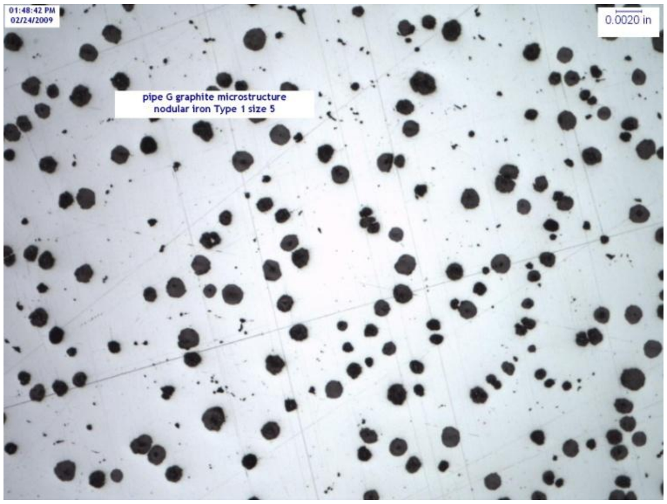

Figure 19. Pipe G Nodular (ductile) iron Type 1 size 5

Figure 20. Pipe H Nodular (ductile) iron pipe

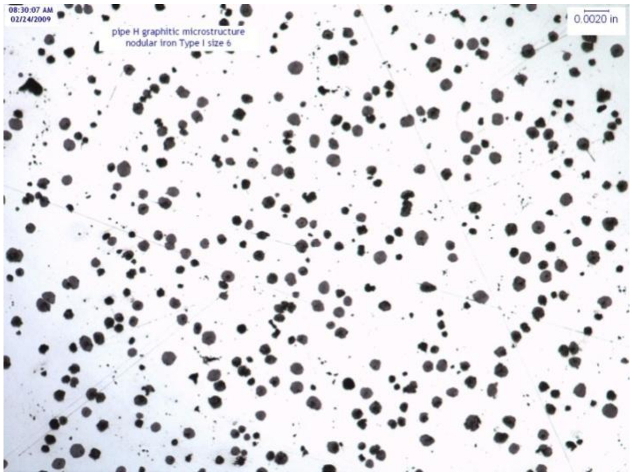

Figure 21. Pipe H. Nodular (ductile) iron Type 1 size 6

Figure 22. Pipe I Carbon steel pipe

Figure 23. Pipe I. Carbon steel (~1025 grade)

Figure 24. Pipe J Gray cast iron Pipe.

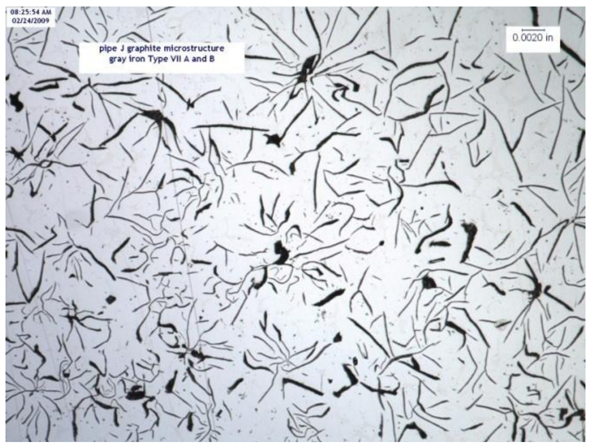

Figure 25. Pipe J. Gray cast iron Type VII A and B

Once the sample pipes were characterized, the work focused on the combined system of the HSK mounted on the FEU. The experimental work demonstrates that the orientation of the antenna to the FEU and its direction of travel must be carefully accounted for in the post-processing of the data.

The experiments were carried out for 1, 2, and 3 antenna assemblies. The finding is that there is an implicit orientation assumed by the software that assembles the various “rings” of pipe data into an image. This must be accounted for to allow the columns in the BEM image to be ordered correctly.

Experiments involving multiple FEU scans per data file were carried out on pipe F. This pipe is .08C high strength low alloy steel with a length of 44 inches and ID 8 inches. Wall thickness varied from 0.264 inches to 0.274 inches measured at the ends. Measured from start end there is burst in the pipe from 22 to 31 inches. The pipe deformation around the burst precludes using the FEU over the entire length of the pipe.

One Antenna Experimental Data

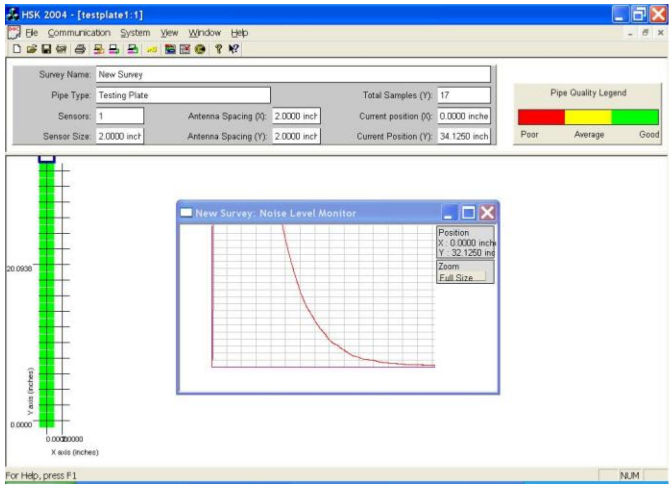

Figure 26 - One Antenna on test plate prior Pipe F "testplate1"

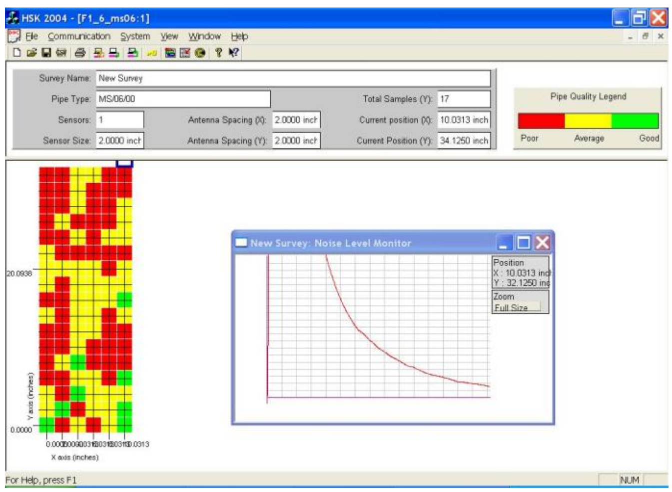

Figure 27 – Multiple Passes of One Antenna on Pipe F

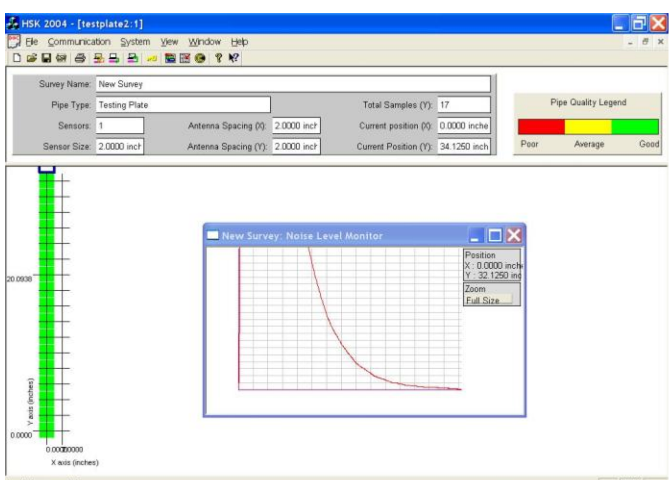

Figure 28 – "testplate2" Test Plate using one antenna after the Pipe F data

Two Antennae Data

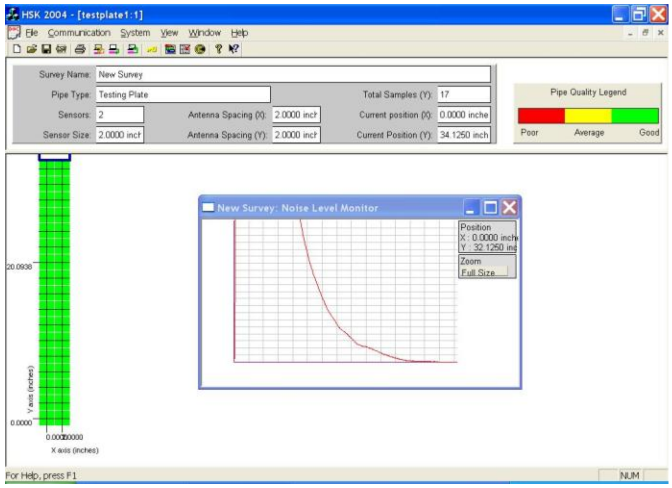

Figure 29 – Test Plate Data using 2 Antennae prior Pipe F data

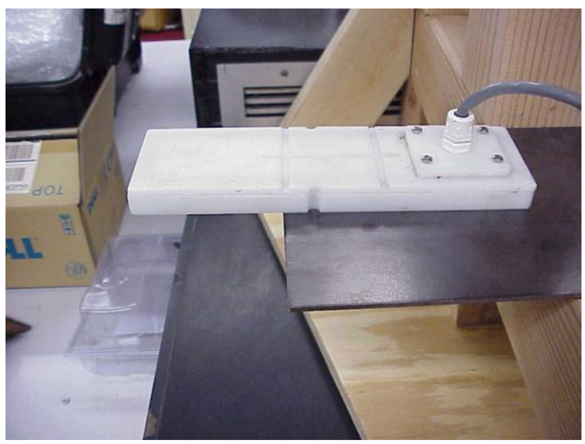

Figure 30 - Two Antennae Sensor; antenna opposite the connector on the edge of the test plate

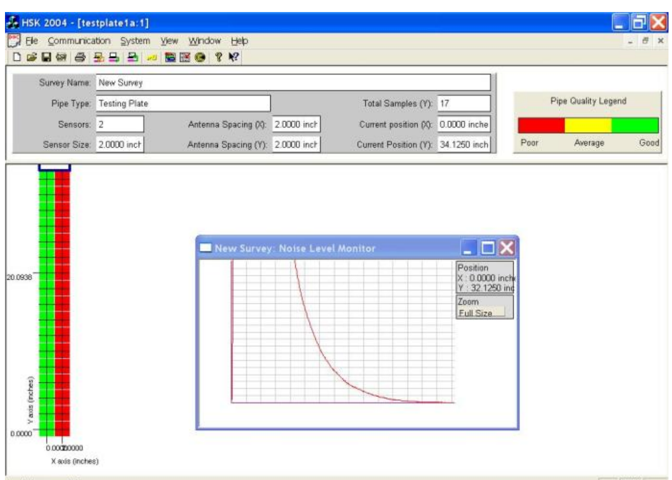

Figure 31 – Test Plate Data; red column of the display off plate

Figure 32 – “testplate1b” using 2 antennae collected with antenna nearest the connector on the edge of the test plate

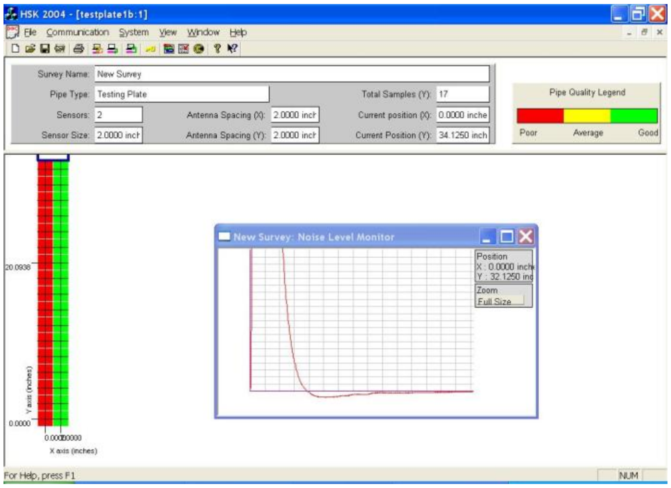

Figure 33 – “testplate1b” shows the antenna next to the connector corresponds to the red data in column 1

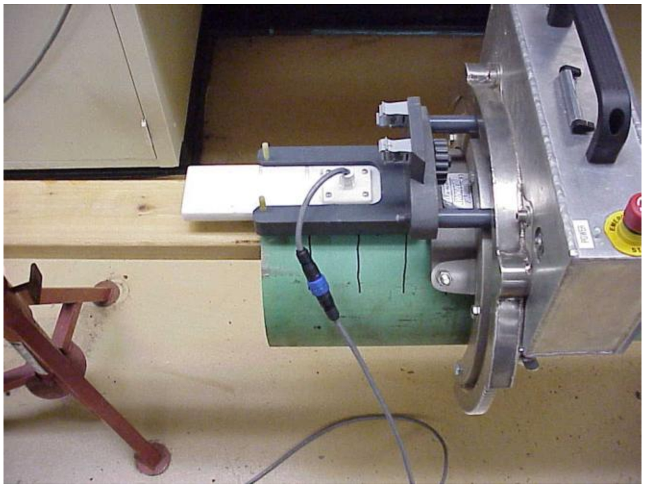

Figure 34 – Two Antennae Data Collection on Pipe F; connector is next to the FEU

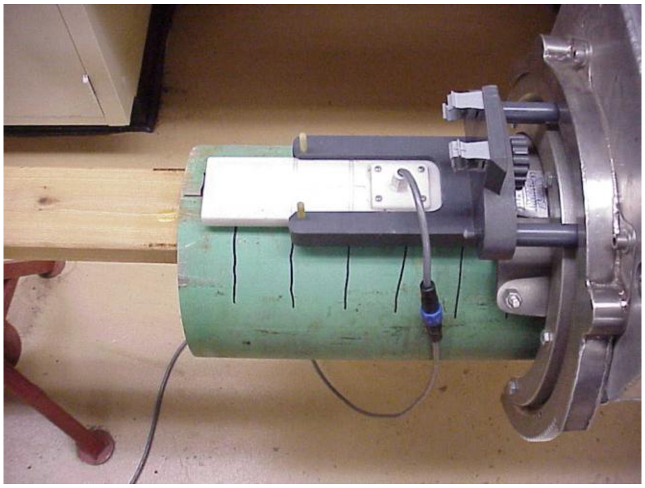

Figure 35 - FEU moved to the next position on the pipe. Ring 3 is positioned at the 2nd mark from the left

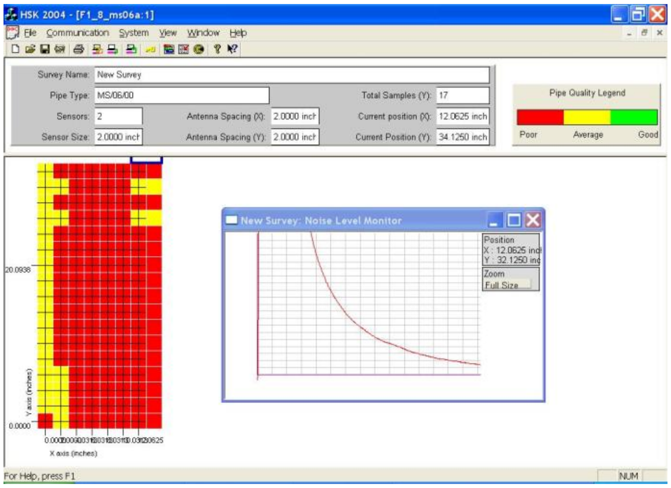

Figure 36 - F1_8_ms06 data order from left to right is 2,1,4,3,6,5. The data columns do NOT map in the correct order, 1,2,3,4,5,6

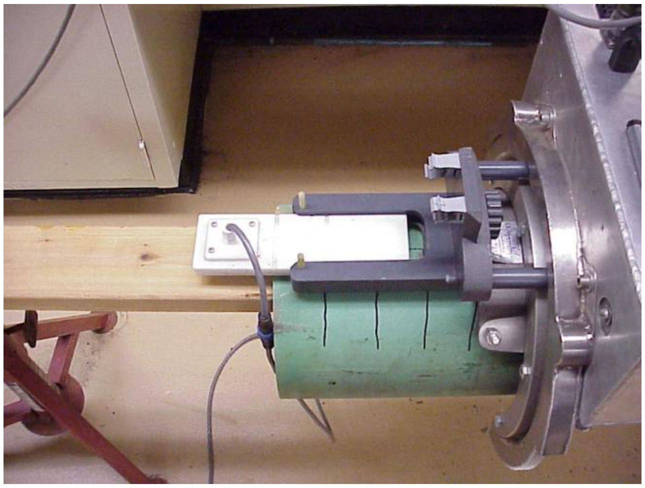

Figure 37 – Data collected with the two antennae sensor inserted into the FEU so that the connector trails as the FEU is moved longitudinally

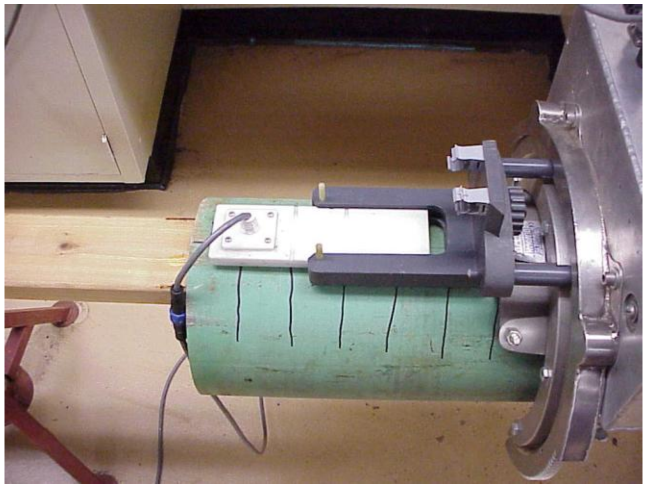

Figure 38 – Two Antennae Sensor positioned to collect data from rings 3 and 4.

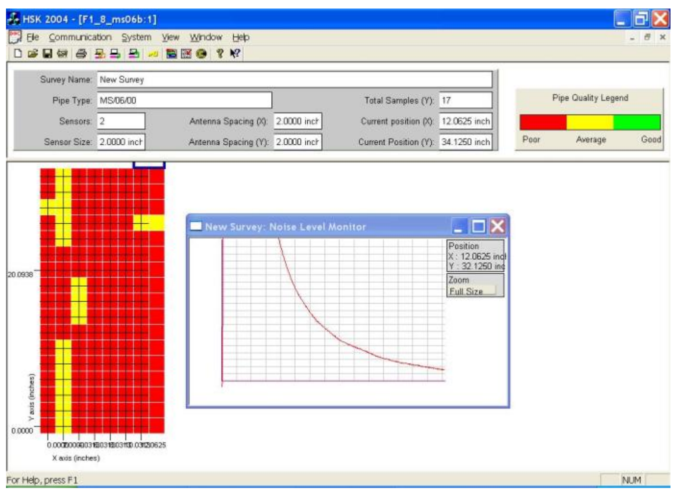

Figure 39 – "F1_8_ms06b" Two Antennae Sensor now has the column data ordered correctly

Three Antennae Data

As can be seen from the above experiments, the software that assembles the collected data into images implicitly assumes that the antenna is advanced with the cable and connector trailing. Failure to do this causes the "rings" of circumferential data to be improperly mapped into the processed image. The experiments were repeated with the three antennae sensor. The test plate was once again used to determine the correspondence of the three antennas in the antenna assembly to the columns in the display. For the three antenna module, antenna A is nearest the connector, B is in the middle and antenna C is the most distant from the connector.

It is demonstrated that unless care is taken in the set up and execution of multiple scans it is possible to map the image data incorrectly. Rather than the expected ordering ABCABC one can obtain CBACBA. Stripes of the processed image can be mirror images rather than correct.

Figure 40 – Three Antennae Sensor with antennae A and B on and C off the test plate

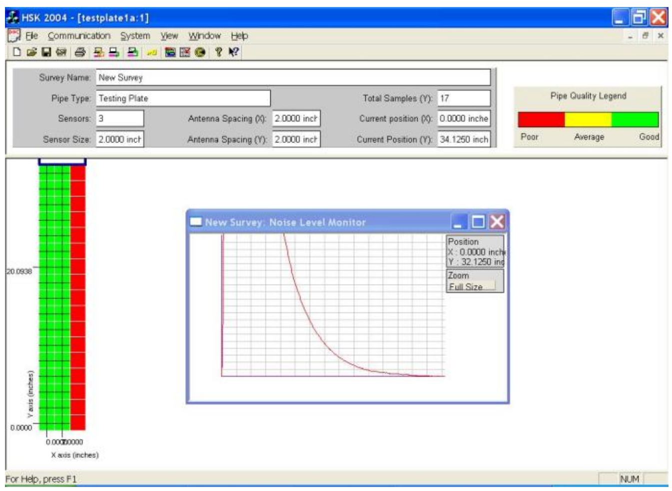

Figure 41 - "testplate1a." Antenna C of the 3 antenna sensor produces the red column indicating it is off the test plate

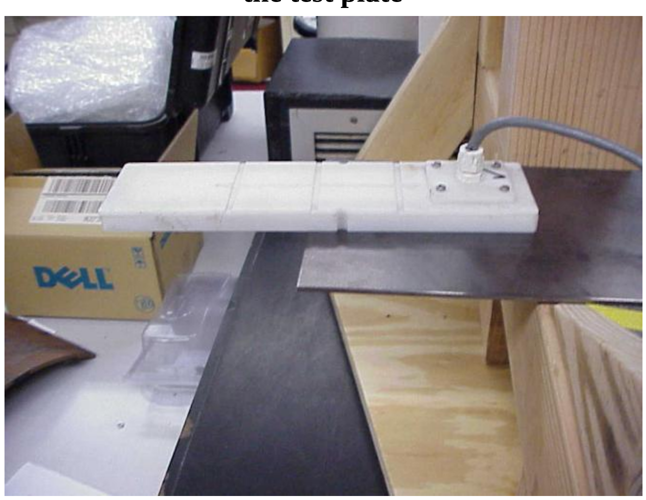

Figure 42 – "testplate1b" both the B and C antenna are off the test plate.

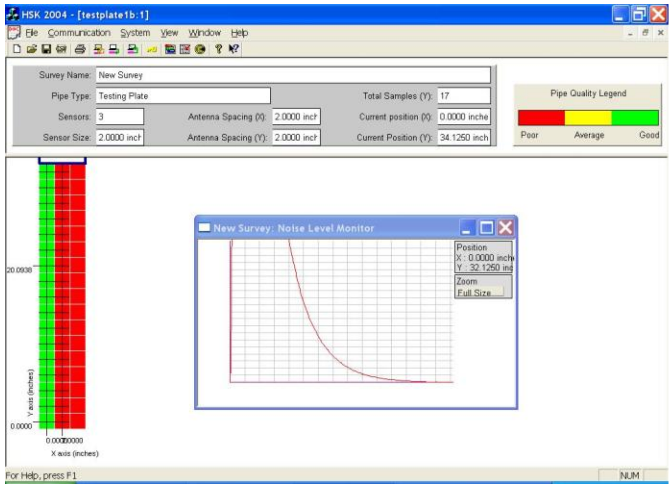

Figure 43 – "testplate1b" shows two columns in red as a result of antennas B and C positions beyond the edge of the test plate

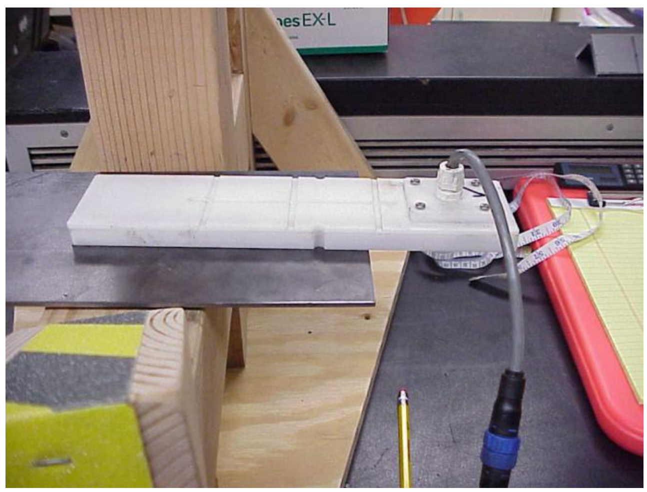

Figure 44 – "testplate1c" acquired with antenna A off the test plate.

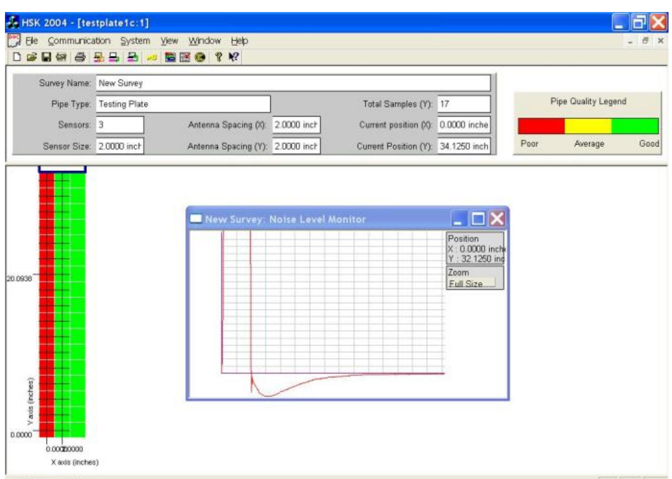

Figure 45 – "testplate1c" confirms that antenna A maps to the left column

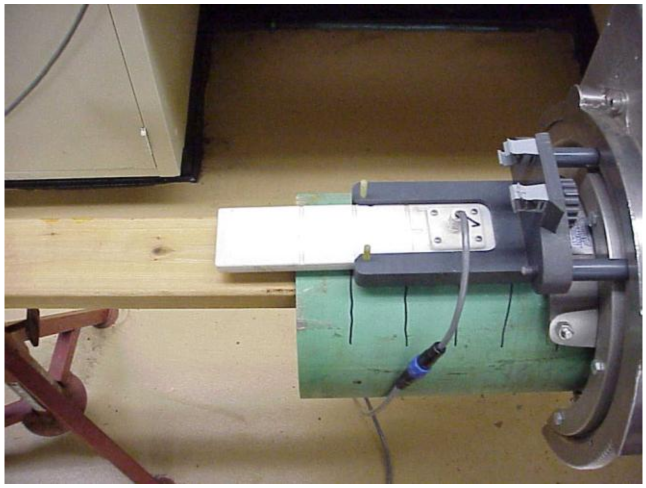

Figure 46 – First Pipe F Scan with 3 Antenna Sensor with cable leading

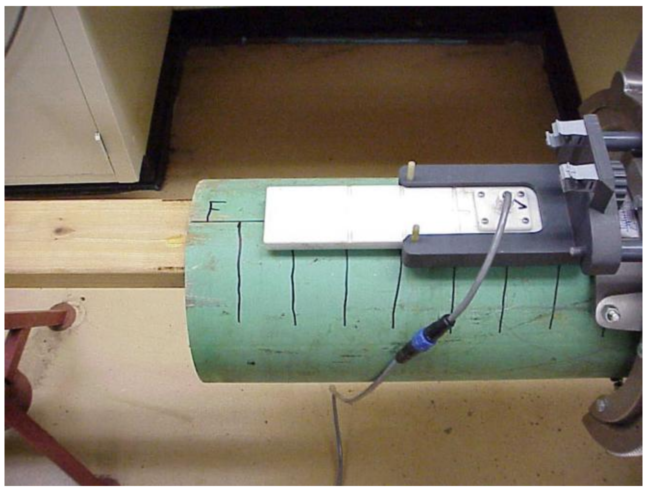

Figure 47 – Second Pipe F Scan with 3 Antennae Sensor

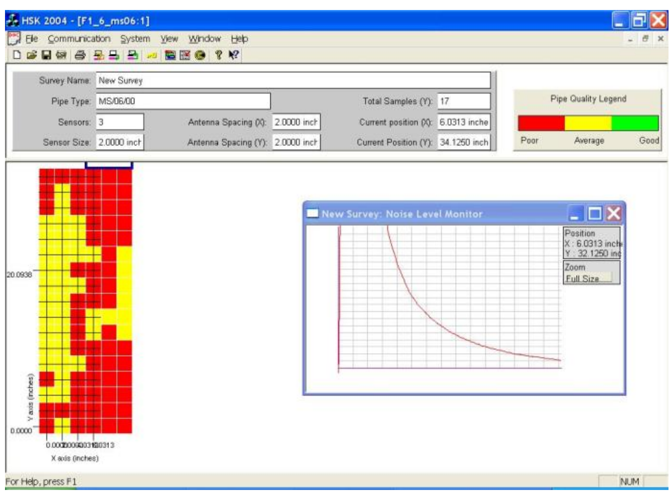

Figure 48 – Data collected in Figures 21 and 22 maps incorrectly

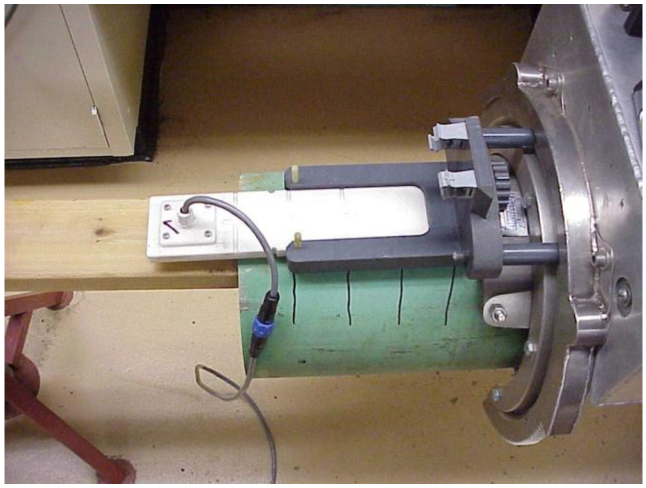

Figure 49 – Scan of Pipe F using 3 Antennae Sensor with cable trailing

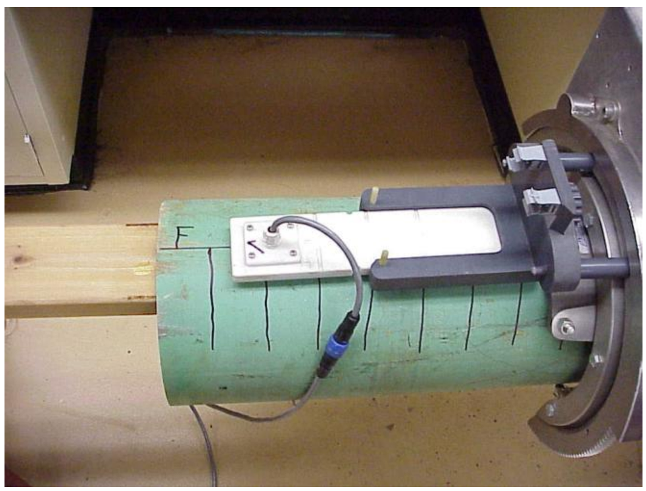

Figure 50 – Pipe F Scan with 3 Antennae Sensor moved to the right

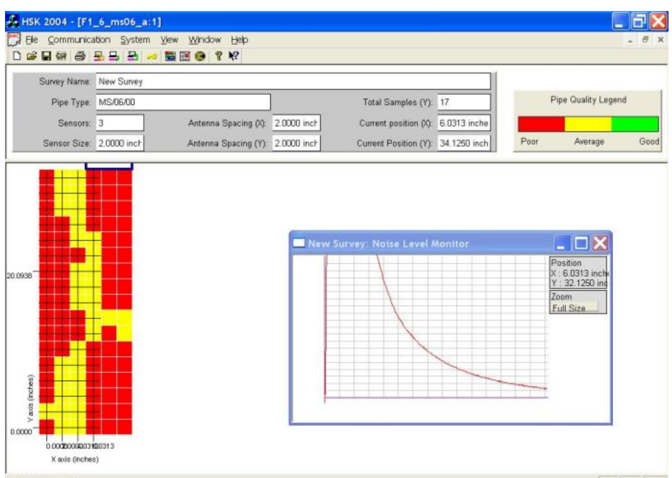

Figure 51 – Setup of Figures 24 and 25 produces the correct mapping of image data.

Six Antennae Tests

RSG provided GTI several multi-antennae arrays and improved software for testing in August 2009. The HSK now includes a complete family of antennae from single elements up to a 1 by 6 array, as shown in Figure 52. There was a need to recalibrate the electronics package of the BEM to work with these improvements. This required that the electronics package be shipped to Australia temporarily. The new antennae and software will allow a finer resolution of features on the pipe being scanned, as shown in Figure 53. The use of 6-element arrays demonstrably speeds up the scanning of a pipe.

Figure 52 – Families of 1 inch and 2 inch Antennae Arrays

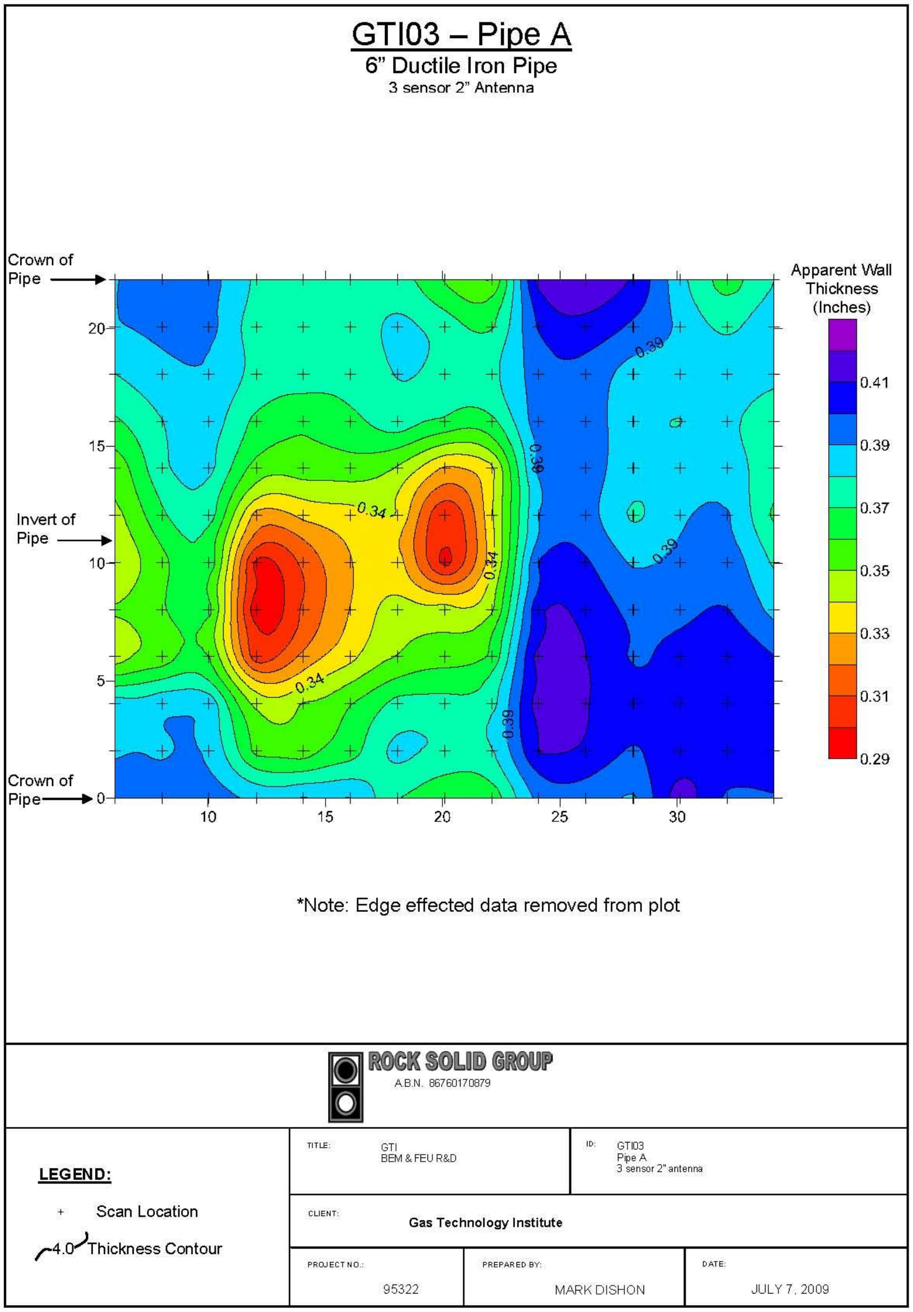

Figure 53 – Processed Data from 1 Inch Antenna Array

Task 3 - Perform Field Evaluations

The purpose of this task is to perform field evaluations of the HSK and the FEU. In April and May 2010 RSG and GTI coordinated and conducted field demonstrations and trials for five (5) utilities. The utilities participating in the trials were Nicor Gas in Chicago, Con Edison & PSE&G in New York, Questar Gas in Salt Lake City, and Southwest Gas in Phoenix. These utilities provided field sites suitable for the demonstration of the operation of the EIS. The EIS which consists of the enhanced Broadband Electro Magnetic (BEM) device & software and the Full Encirclement Unit (FEU) was successfully deployed at each site allowing the collection of BEM data. The collected data was post-survey processed and in each case presented as part of the field demonstration overview the following day.

These field demonstrations were successfully completed between the 27th April and 6th May 2010. Aside from clearly demonstrating that the EIS is now at a stage of field deployment, the field application showed the flexibility of the system from scanning heavily encrusted cast iron pipe to well coated, relatively new and clean carbon steel pipe. The demonstrations also allowed RSG & GTI to show that meaningful data could be collected with or without the necessity of deploying the FEU as well as the ability to post-survey process data affected by cathodic protection (CP) systems.

Scanning was successfully undertaken along pipes exposed in excavations and pipes retained at the yard of Con Edison. The scanning was completed on a range of pipe materials including cast iron and carbon steel, some were coated and some were heavily encrusted.

All scans were undertaken using the FEU about the outside circumference of the pipes. Where possible, real-time displays were available on site however these were limited due to the relatively small sample range in the Database selection at the time of scanning. Close approximations had to be made where the correct Database was not available and the final appropriate results were made available following the full post-survey processing.

Ultimately, the field demonstrations highlighted the need to take the current state-of-the-art EIS and start utilizing it in the field in earnest. It is only with this approach that RSG & GTI can refine the EIS by populating the MetCon Database and expanding the FEU capability range and ultimately drive the EIS to the development of the Keyhole Inspection System (KIS).

RSG has prepared detailed reports of these field trials which are attached to this report as Appendix B.

Task 4 – Guidelines and Procedures

The purpose of this task is to transfer the knowledge gained during the execution of the project to the end users. An operator’s manual, covering the set up and operation of the BEM-FEU system has been prepared by GTI and RSG. Utility feedback from the field evaluations will be incorporated into the manual. The completed manual is attached to this report as Appendix A. A presentation on the project results was given at the 2010 Fall AGA Corrosion Committee meeting in Columbus, Ohio.

Results and Conclusions

The project goals are to:

- Demonstrate how to use the BEM-FEU system to utilities in the United States,
- Provide documentation and training on using the BEM-FEU system, and
- Provide enhancements for the BEM-FEU system that simplify its use.

This project has allowed RSG to bring the BEM technology to a stage where it is configured and suitable for integration with the FEU as part of the field automated EIS configuration. The EIS is now available as an advanced commercial device for pipeline scanning and condition investigations. To make it truly field-worthy the need to populate the Database is the essential next step prior to incorporation into standard field applications. The resulting EIS devices can now be deployed by an operator with limited field skills or knowledge of corrosion analysis and their task is largely limited to clamping the antenna assembly to the pipe and activating the data acquisition software (MetCon). The new MetCon software is now suitable for both imperial as well as metric units. The HSK1000 components entering the pipe excavation are also fully waterproof and can be operated in wet or submersed pipe conditions. While the current EIS does not have a comprehensive range of pipe diameters, this capability can easily be added by changes to the FEU.

The aim of the field demonstrations was fulfilled and successful scans were completed at each demonstration location. The field demonstrations showed that the current state-of-the-art equipment is a well advanced prototype with a robust BEM component in the form of the HSK1000 and a reliable FEU. In each case meaningful BEM data was collected and although the FEU failed to complete the scanning in New York for Con Edison this enabled us to demonstrate the flexile nature of the technology in that the scanning was finished via hand scanning. To move forward towards integrating the EIS unit into the “pipe assessment” toolbox of direct assessment techniques it is essential to get the EIS in its current form out into the field for regular use. Regular frequent use of the EIS by a utility will allow us to further develop the system to be more field-worthy and importantly it will provide critical pipe information necessary to build and expand the database necessary for the MetCon software so that the user can confidently assess the real-time display. Additional use of the EIS will also allow us to assess the need for larger diameter FEU devices for application to large diameter mains so that the EIS is suitable for both distribution as well as transmission mains. RSG & GTI are able to arrange for the supply of the EIS or just the HSK1000 if the clamp-on FEU is not required for immediate utility application.

On-going negotiations with utility providers for the longer term use of the EIS continue. This is considered essential to allow the development of a broader range of Database entries and thus a confident condition interpretation of the pipe based on real-time displays on site.

Respectfully Submitted,

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Martin Roubal

Appendices

Appendix A is the Operator's Manual for the HSK-FEU system. This manual incorporates feedback from the field demonstrations of the system.

Appendix B is a series of reports that detail four test sites. Analysis of the data and conclusions are presented.